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Information Support Technology of Ship Survey Based on Case-based Reasoning

Cao Jiyin*[1], Fan Shidong[1], Lu Wen[1], Liu Haiyun[2]
[1] Energy and Power Engineering College, Wuhan University of Technology, Wuhan China
[2] Metallurgy and Power Engineering College, Hebei United University, Tangshan China
*Corresponding author, e-mail: caojiyin_whut@163.com

Abstract

Recently, the significance of ship inspections has been increasingly recognized because sea pollution and safety problems are occurring more and more frequently. Currently, most ship inspections rely on the experience and professional knowledge of the workers. Hence, it is difficult for new workers to assess the ship state in the ship inspections.The present problems are that the ship inspection technical support level in China is not balanced, especially as to the current situation with low level, poor technologyin under-developed areas. In this paper, the case technology about the case-based reasoning to the ship inspection is proposed. The methods of normative inspection case representation are discussed.This is considered to be the basis of case-based reasoning. Then the tertiary case structure with the index is defined, in which the K-nearest neighbor method to calculate the similarity between caseswas used so that the ship's inspection information can be searched effectively. In addition, an improved retrievalstrategy of the nearest neighbor method is introduced. Therefore, in the inspection site, the inspectors can acquire support information by the case bases, and then the new cases are calculated automatically. Further, a ship inspection case management was introduced to improve the stability of the system. By carrying the case-based reasoning into an inspection, an inspector can generate fault information and inspection information simply and easily. Some examples of the organization and retrieval are shown at the end of the paper.

Keywords: *ship inspection, case-based reasoning, case retrieval, K-neighbor method, case management*

1. Introduction

With the rapid development of our country's shipbuilding and ship transport, the volume of ship inspection business will also synchronous grow [1],[2]. In order to ensure the safety of navigation, job security and prevent the pollution of the marine environment, it needs ship inspection to ensure that the ship have a good technical condition [3]. Ship inspection institutions can inspect the marine materials, mechanical equipment and marine engineering facilities according to the provisions of state and the relevant procedure, so that the ship will meet the requirements of the relevant international conventions and follow the national laws, regulations and the technical indexes of inspection agency rules [4]. Therefore, it is very important to improve the quality of the ship inspection [5].

Currently, ship inspections are poorly controlled, and their details rely on the empirical knowledge of the persons in charge. Therefore, the business capability and knowledge classification survey data of a Surveyor directly affects the quality and level of the ship inspection [6]. In this situation, ship inspection ability of the ship management department very difficult to improve, resulting in low ship inspection technical support level in China.

By the support of the modern computer technology [7], network technology [8], information technology [9], ship inspection technology is also in the new changes. Smart, efficient, and reliable is the goal of modern ship inspection technology research. The technology of case-based reasoning is one effective method of solving this problem.

Recently, the case of surveyor using knowledge to solve the problem of ship inspection is gradually increasing. The inspection institutions often consume a large amount of manpower, material and precious time resources when facing the ship inspection. Therefore, we can standardized manage the ship inspection knowledge and experience of the existing regulations, and use the case-based reasoning mechanism to guide solving the subsequent problem. It is of great help for inspectors to reduce the research time, ensure the quality of inspection.

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Currently, the case-based reasoning has been used in many other fields. A solution retrieval system for expert finding and problem diagnosis by using case-based reasoning was proposed [10]. And a hybrid model was developed by integrat-ing a case-based data clustering method and a fuzzy decision tree for medical data classification [11]. In the ship field, an automated case learning method for CBR-based collision avoidance systems was introduced [12]. However, the technolo-gy of case-based reasoning has not been used for ship inspection.

In this paper, we make a preliminary study of the case representation of ship inspection and the build issues about the case base. In addition, the ship inspection case frame model is constructed and the case retrieval strategy by the purpose of researching the ship inspection technical resources is discussed. The last, an information technology to support ship inspections, which uses the case-based reasoning for ships, is comprehensively examined.

2. Case Representation of Ship Inspection

2.1 Case-based Reasoning Technology Overview

CBR (Case-based Reasoning) technology originates in the United States Yale university Roger Schank in 1982 in the Dynamic description of the Memory, is a new rise in the area of artificial intelligence, is an important knowledge-based problem solving and learning method. It is to solve the problem by reusing or modify the solution to the problem of similar before [13]. As we all know, human beings always search from their memories for similar problems that they have solved success-fully in the past to find a solution, when they are confronted with a new problem. The so-called experience is stored in CBR system in the form of cases. When encountering new problems, CBR systems search case base for similar experiences to count on.

Using case-based reasoning mechanisms to guide the resolution of ship inspection problems, can reduce testing time, improve test efficiency and assure inspection quality, so that inspection tasks can be successfully completed by low technological level surveyor. There are commonly four cyclical processes in CBR [14], besides the attempt in trying to build-up a high quality case base [15] and represent cases: Retrieving similar cases; Reusing solutions of similar cases; Revising the proposed solutions; and Retaining the new case.

The ship inspection technology based on case -based reasoning is similar to other methods to solve the problem with the CBR, is shown in figure 1.

A case is used to represent the state description of a problem and its solution strategy. The primary mission of designing a Case-based reasoning technology ship inspection case library is to represent ship inspection technical information as the form of case reasonably and effectively.

2.2 Case Tepresentation Method

Case representation must be based on the various existing knowledge representation, almost all existing knowledge representation can be used as case representation method [16]. For the same case, Cases can be expressed using different methods. However, to solve a problem, Different representations may produce completely different results. Therefore, for solving the problems in different areas, select the appropriate case representation is very important. A technical case of ship inspection contains test items, inspection location, inspection standards and so on. Therefore, a single case of representation is difficult to meet the needs. In this paper, object-oriented technology and database technology combined into the case representation.

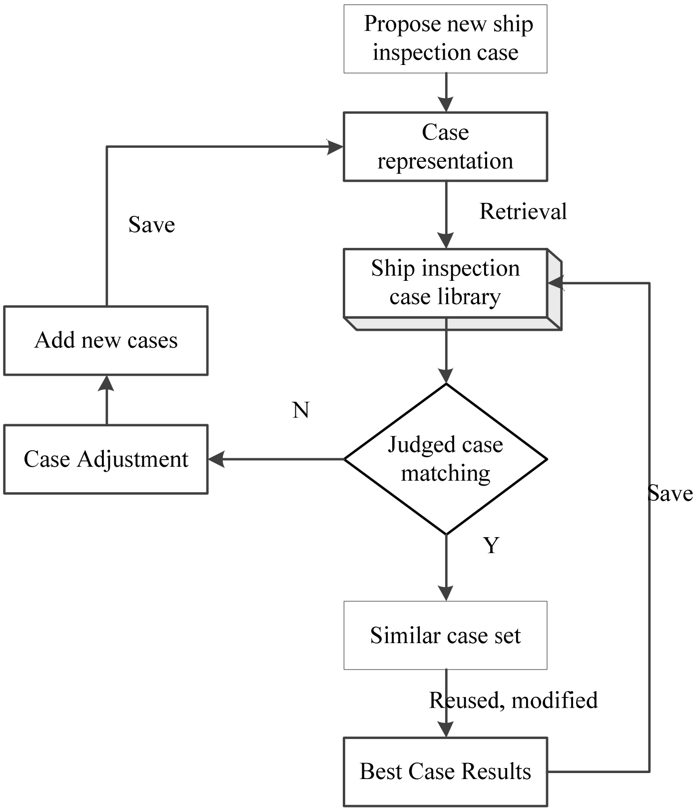

Figure 1. Basic steps to solve the ship inspection problem based on CBR

So the advantages of representation can be used. And using this method can also make good use of inheritance relationship of classes, establish a hierarchy between cases, facilitate the organization and retrieval of case library, package attribute data、case retrieval、modification methods、preservation methods and so on. Dynamically construct case-objects when the system is running[17],[18].

2.3 *Case Representation of Ship Inspection*

Case content usually consists of three parts <Description of the problem, Description of the solution, Description of the effect>
(1) Description of the problem: Described the state of environment when the problem occurs.
(2) Description of the solution: Illustrates the solution for the problems.
(3) Description of the effect: assessment and summary of treatment plan.

So, case of ship inspection that based on case-based reasoning can be defined as a quadruple:

$$C = \langle D, S, R, T \rangle \tag{1}$$

In which, $D = \{d_1, d_2, d_3, d_4 \dots\}$ is a non-empty finite set, it represent description of ship inspection, including case number, ship parameters, ship inspection processes, type of ship's inspection; $S = \{s_1, s_2, s_3, s_4 \dots\}$ is a non-empty finite set, it represent feature set of ship inspection case; R is conclusion information of case; T is feedback of case. So, a ship inspection case can define objects of structure shown in Table 1.

Table 1. Structures of Ship InspectionCase

Structure	Content
Description of ship inspection case	case number ship parameters ship inspection processes …
feature set of ship inspection case	type of ship inspection eigenvector weight vector conclusions
conclusion information of case	IETM certificates …
feedback of case	evaluation of results and summary case study quality the number of successful match reusability

Case for ship inspection feature set is described in detail, ship inspection Case feature set is a non-empty finite set, representing the value, property and data type of each feature.

(1) Ship inspection Case Eigenvectors

Ship inspection case eigenvectors means all eigenvalues composed in a certain order vector, after parameterized treatment. The main features include: ship inspection regulatory requirements, previous surveyor inspection data, environmental parameters etc. Before carrying out case reasoning, characteristic values must be expressed as a range or limited set of values. Ship inspection feature vector is expressed as:

$$A=\left[A_1(1),\ A_2(2),...,A_i(k),...,A_i(n)\right], i\in[1,m], k\in[1,n], A_i$$

means ship inspection eigenvectors in the i-th case, $A_i(k)$ means the eigenvalues that come from the k-th indicators after the parameterized treatment in the i-th case. As the statutory inspection characteristics to diesel, of which ship inspection characteristics general performance as three types:

a. Logic type. State exists only True or False.0 means the sign does not appear,1 means the sign appear. Like the safety interlock between power transfer device and starting device in diesel engine:

$$V(a_i)=\begin{cases}0 & a_i=TRUE\\ 1 & a_i=FALSE\end{cases} \tag{2}$$

In which, a_i is the i-th attribute, $V(a_i)$ is the value of it.

b. Numeric. Quantitative data, Such as power、speed、commutation time of a diesel engine, ship inspection process is always considered that the value is in a range of reasonable, regulations also provides in a range. For this feature, Case characteristic value is equal to the actual measurement value of ship inspection data. Ship inspection case attributes have different dimensions and orders of magnitude in practical applications, so it must be unified before we need apply these properties.

$$SIM(X,Y)=1\text{-}DIST(X,Y)=1\text{-}\sqrt{\sum_{i=1}^{n}W_i\times D(X_i,Y_i)} \tag{3}$$

In which, V_i is property values, $\mathrm{sim}\,(V_1,V_2\ldots V_i)$ is attribute values after dimensionless transformed, and $\mathrm{sim}\,(V_1,V_2\ldots V_i)\in[-1,1]$.

c. With a text description of the disorder enumeration data. For example, boiler feed water pressure: “too large, normal, too small” etc. In order to facilitate data processing, we required to digitize them. We can establish the corresponding index table, scilicet, create a index table of which property and Its index value are corresponding. Index values are represented with integers 0, 1, 2 etc. Particularly, provides that all normal attribute values can be represented with 0.Different situations have different attribute indicates, you can make the appropriate changes, table 2 shows the index table.

Table 2. Disordered Data Indexing Table

Index	Property
0	Normal
1	Too high or too large etc.
2	Too low or too small etc.

(2) Case characteristics weight vector

Different case characteristic attributes in ship inspection function is different in ship inspection process. By introducing the weight vector, it makes the results of similarity calculation more reasonable [19].The traditional methods for determining a feature weights contain consulting experts, domain knowledge, survey statistics, etc. These methods are simple, fast but due to over-reliance on subjective judgment and experience, it is sometimes difficult to get a reasonable solution case. Non-traditional methods contain genetic algorithms (GA), Analytic Hierarchy Process (AHP), which overcomes the shortcomings of traditional methods. But the algorithm is complex and it is difficult to achieve. Knowledge in this field will adopt laws and rough set theory combined method to extract the weights. Case feature weight vector can be expressed as: {Case feature weight, number weight value} two parts. Due to space limitations not described in detail here.

3. Organization and Retrieval of Ship Inspection Case Base

3.1. Ship Inspection Case Base Organization

Organize the index case is convenient for the retrieval. According to the characteristics of the ship inspection, the retrieval strategy combining ship inspection process with the nearest neighbor algorithm is taken in this paper. When the case base is small, and the any two properties are mutually independent, the simplest and nearest neighbor algorithm is the most effective retrieval techniques. But when nearest neighbor method is used to calculate the similarity, each case has to be calculated again. As the case base increases, it will definitely lower case retrieval efficiency, it is necessary to organize the case base. Now, shipping test case library will be divided into three classes, the inspection processes of which are different. The construction inspection process of a 27000DWT multi-purposes vessel was taken as an example, the case base structure shown in Figure 2.

Each type of specific cases constitutes a smaller specific case library, namely a specific layer. Selecting a representative of case in the specific case as the index of the category of cases, all class representatives constitute a representative case base, which belongs to an abstraction layer and is a typical, representative case, on behalf of a class case in retrieval. Process-level Case Library refers to a case base under a inspection process. When searching it, the first step is to determine which one process in a inspection mode, then to find the most similar representative case on representative case base (this step is equivalent to new issues of classification, to judging which category of cases it belongs to), finally to conduct further retrieval in the most similar case corresponding to the case of that kind.

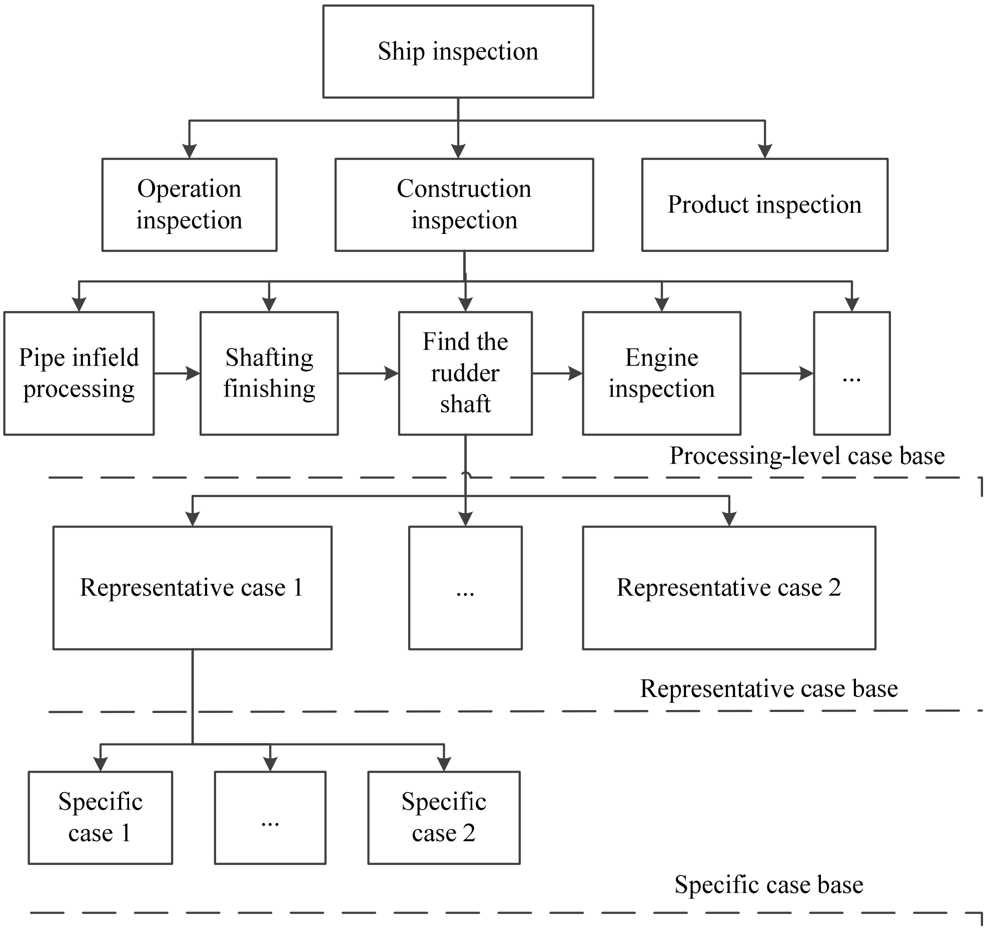

Figure 2. Ship inspection case base structure

3.2.Similar Design of Case Base

The fundamental purpose of invoking cases is to compare the similarity between the case in base case and the problems to be solved and find the most similar cases. Thus, the similarity is the basis for calling case.

This paper takes K-nearest neighbour method searching method to calculate the similarity between cases [20]. Where the nearest neighbor method (Nearest Neighbor Method, NNM) is a special case of K-nearest neighbor method (K=1) [18].

Supposing $X=\{X_1, X_2,\cdots, X_n\}$, $X_i\,(1\le i\le n)$ is its i-th eigenvalue. W_i is its weight. X is a point of n-dimensional feature space $D=(D_1\times D_2\times\cdots D_n)$. $X_i\in D_i$, As the X, Y in space D, X, Y distance on D is followed:

$$DIST(X,Y)=\sqrt[r]{\sum_{i=1}^{n}W_i\times D(X_i,Y_i)^r} \tag{4}$$

$$D(X_i,Y_i)=\begin{cases}0 & \text{When } D_i \text{is discrete, and } X_i=Y_i\\ 1 & \text{When } D_i \text{is discrete, and } X_i\ne Y_i\\ \dfrac{|X_i-Y_i|}{\max_i-\min_i} & \text{When } D_i \text{is continued}\end{cases} \tag{5}$$

Where: $\max_i$ and $\min_i$ denote the maximum and minimum values of the property respectively, when r is 2 in the formula (4), $DIST(X,Y)$ is the Euclidean distance.

When the distance between the case is defined, then the similarity between cases can be defined as:

$$SIM(X,Y) = 1 - DIST(X,Y) = 1 - \sqrt{\sum_{i=1}^{n} W_i \times D(X_i,Y_i)} \tag{6}$$

3.3. Search Strategy of Case

Case retrieval is not only a key step to achieve CBR, but also the core of CBR expert system. The main purpose is to retrieve a group of similar cases as little as possible from the case library based on the new problem definition and description, which have reference value to the problem as the basis for solving new problems. Typically, case knowledge searching strategy has nearest neighbor strategy, inductive reasoning strategies, knowledge guiding strategies, templates retrieval strategies and so on. Whether search strategy selection is appropriate, the high-speed and efficient completion of case retrieval performance has a direct impact on problem solving.

The detailed steps to retrieve in the case of a class library are followed:

(1) Comparing new issue with the m case in the library (comparison of n conditional attribute), the compared results are saved as a matrix of the form:

$$\delta = \begin{bmatrix} \delta_{11}\ \delta_{12} \cdots \delta_{1n} \\ \cdots\ \delta_{ij}\ \cdots\ \cdots \\ \delta_{m1} \delta_{m2} \cdots \delta_{mn} \end{bmatrix} \tag{7}$$

Where i = 1,2 ……m, j = 1,2…… n. i denotes the i-th case, j represents the j-th conditional attributes, δ_{ij} is the local similarity comparing new problems with the i-th case of the j-th condition attributes

(2) The weight vector $[w_1\, w_2 \cdots w_n]^{\mathrm{T}}$ is multiplied by the matrix δ (w_j is the j condition attribute weights), the result of which is $[\delta_1\, \delta_2 \cdots \delta_n]^{\mathrm{T}}$, namely the overall similarity between the new cases and each of the m case. Specific formula is as follows:

$$\delta = \begin{bmatrix} \delta_{11}\ \delta_{12} \cdots \delta_{1n} \\ \cdots\ \delta_{ij}\ \cdots\ \cdots \\ \delta_{m1} \delta_{m2} \cdots \delta_{mn} \end{bmatrix} \times \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix} = \begin{bmatrix} \delta_1 \\ \delta_2 \\ \vdots \\ \delta_n \end{bmatrix} \tag{8}$$

(3) Selecting a or k cases with the maximum value of a degree of similarity as a search result. Retrieved case may be positive case scenario or counterexample. Positive examples provide experience, while counter-examples provide a lesson, which can avoid repeating past mistakes.

w_j, as the value of the property rights of the case, reflects the degree of influence which the property has on the results .the reasonable weights has great inference on the accuracy of the results of the case. There are usually two setting methods: one is for the surveyor to set the level of experience, which has a high degree of subjectivity; another way is the analysis and calculation of existing historical data to get derived weights objectively.

In order to achieve the objectives, namely rapid retrieval of similar cases of current cases and of the matching case as little as possible, this paper established a shipping inspection case retrieval model, shown in Figure 3.

The specific implementation process is as follows:

(1) Judge cases in the process under some kind of inspections through the human-computer interaction interface.
(2) Find the most similar case in the representative case base using the nearest neighbor method (K = 1). The representative case is putted forward with new cases, and the rest are filtered out. This step is equivalent to classify new cases which belong to the representative case.
(3) Put forward K neighbor method for further retrieval in a related specific case to find the most similar case.

In the last two stages, set two similarity threshold respectively, $\theta_1 (0 < \theta_1 < 1)$, $\theta_2 (0 < \theta_2 < 1)$, only a case similarity which is greater than the corresponding thresholds is chosen . The two thresholds can artificially set.

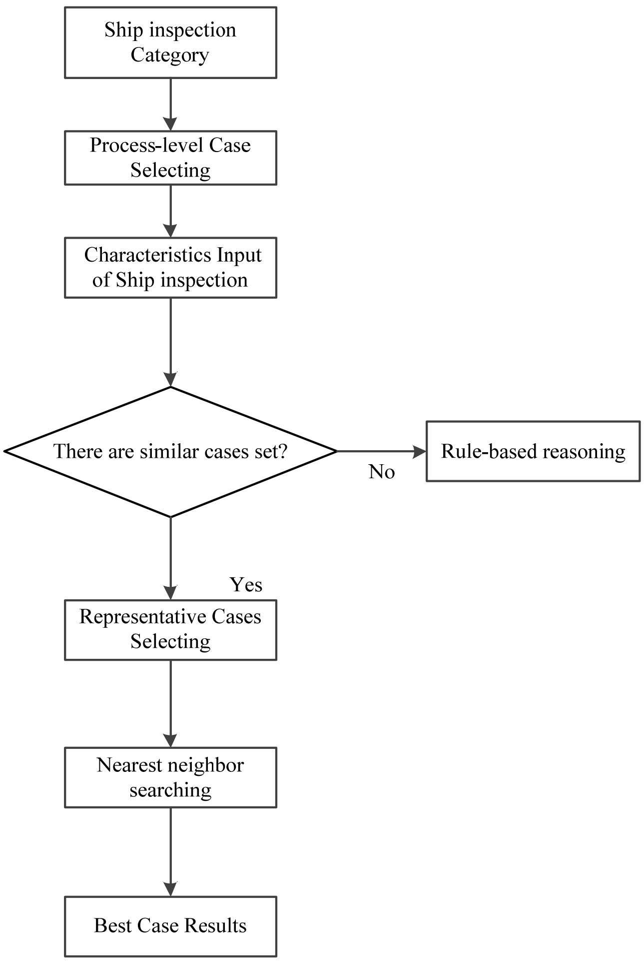

Figure 3. Retrieval model

4. Case Management of Ship Inspection

CBR-based ship inspection depends on not only the performance of case base case representation, reasoning and retrieval strategies, but also the case management and maintenance. So the CBR case base management system is an indispensable part.

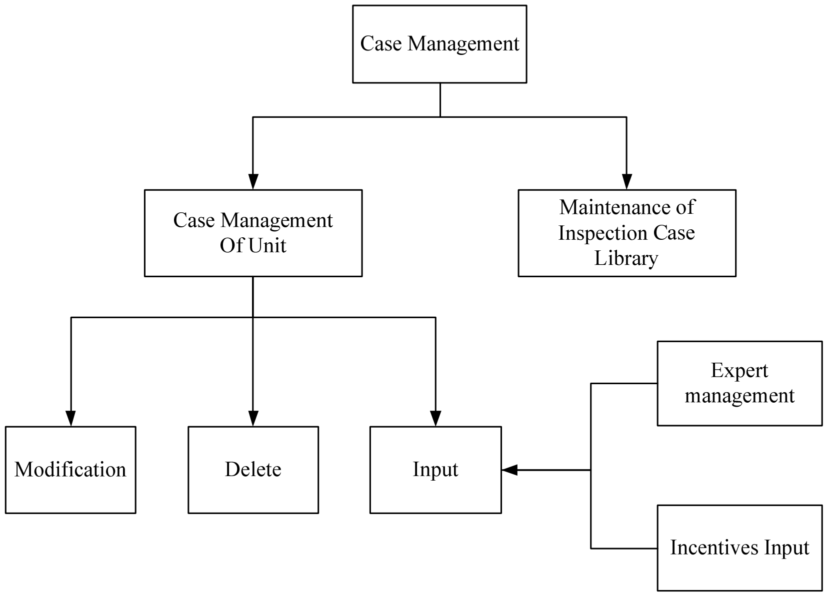

Figure 4. Ship inspection case database management

4.1. Unit Case management

(1) Adding new case is the case base passive learning process. In order to keep rich library of the case, in addition to expert or professional organization surveyor can get actual cases or data storage consolidation, local ship inspection personnel should also establish incentive mechanisms to encourage their participation in the work, to mobilize the enthusiasm of the entire industry maximize the wealth of case base.
(2) Case corrected. Case amendments include amendments to the content of the case and case structure optimization. Case content correction refers to revise characteristic attributes, attribute weights, and treatment options of ship inspection case.
(3) Case deleted. Case base capacity is not better when it is bigger. In the progress that application based on CBR case base ship inspection, there may be some cases of mismatched or slave. Therefore, the knowledge base should be streamlined on a regular basis, and make the necessary deletion under the guidance and participation of the professionals.

4.2. Maintenance of Ship Inspection Case Library

In order to maintain the efficiency of reasoning and inference accuracy of the results, case base should be controlled at a certain scale, and the potentially misleading cases (noise) on the case base should be deleted or updated. And timely optimize the organizational structure and storage structures of case library.

5. Examplesand Results

5.1. Example of Case Base Organization

The fault in the marine engine fuel system and cooling system occurs frequently, so it uses the two parts of a fault to analyse. The inspection fault cases presents as a form of decision table, then uses rough set theory to calculate. The decision table contains six conditions properties: torque, temperature, the throttle opening, air flow rate, rotational speed and pulse width. Decision properties are fault types, including six kinds of failures: normal, cooling water temperature is too high, a cylinder has no injection circuit, torque sensor circuit, temperature sensor circuit, air flow sensor is damaged, respectively corresponding to 0,1,2,3,4, and 5.

Table 3. Engine Inspection Failure Case

Case number	Torque (V)	Temperature (V)	Throttle percentage (V)	Air flow rate (V)	Rotational Speed (r/min)	Pulse width (ms)	Fault types
1	0.373	0.282	0.943	1.406	1317.6	4.49	2
2	0.31	0.83	1.07	1.625	1797.4	4.136	0
3	0.952	0.231	1.641	2.403	1855.6	7.638	0
4	3.179	0.498	2.072	1.676	1255.0	5.857	3
5	0.419	0.572	0.727	3.747	687.4	4.5	5
6	0.483	4.957	0.942	1.396	1053.9	5.224	4
7	1.26	0.055	1.726	2.314	1411.4	9.376	1
8	0.84	0.154	1.626	2.285	1403.3	8.8	2
9	0.637	0.389	1.223	1.821	1350.986	6.864	0
10	0.415	0.943	0.857	1.26	1123.007	4.288	0
11	1.575	0.077	0.938	2.754	1760.563	11.068	1
12	3.194	0.97	1.38	2.009	1210.38	7.888	3
13	0.39	0.665	0.727	3.767	625.904	4.5	5

Table 4.Similarity Matrix of Case 4

	{1}	{2}	{3}	{7}	{8}	{9}	{10}	{11}
{1}	1	0.8924	0.6449	0.5019	0.5675	0.8483	0.8595	0.3286
{2}	0.8924	1	0.6230	0.4687	0.5357	0.8212	0.9152	0.3024
{3}	0.6449	0.6230	1	0.8293	0.8882	0.7925	0.5851	0.6724
{7}	0.5019	0.4687	0.8293	1	0.9108	0.6440	0.4442	0.8247
{8}	0.5675	0.5357	0.8882	0.9108	1	0.7103	0.5089	0.7522
{9}	0.8483	0.8212	0.7925	0.6440	0.7103	1	0.7828	0.4743
{10}	0.8595	0.9152	0.5851	0.4442	0.5089	0.7828	1	0.2775
{11}	0.3286	0.3024	0.6724	0.8247	0.7522	0.4743	0.2775	1

Make a clustering analysis of these cases, use MATLAB for computing, a similarity threshold value η=0.7 . The final clustering tree is shown in Figure 4.

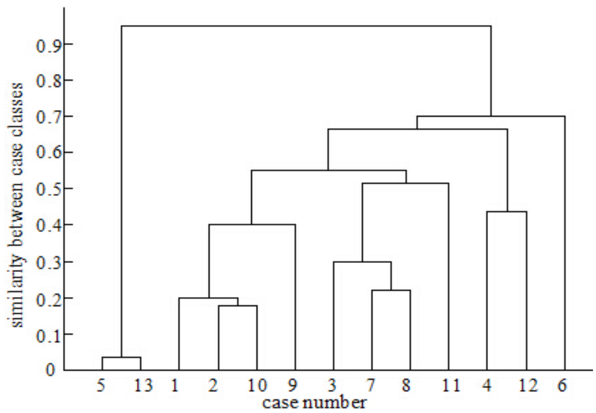

Figure 5. Clustering Ttree of Cast Base

So, the 4 specific cases are put forward: CASE1={6}, CASE2={5,13}, CASE3={4,12}, CASE4= {1,2,3,7,8,9,10,11}. Taking an example of the CASE4= {1,2,3,7,8,9,10,11}, the Similarity matrix of case is shown in table 4.

The sum of the similarity case 1 to with other cases: L= 0.8934 + 0.6439 + 0.5018 + 0.5675 + 0.8483 + 0.8595 + 0.3286=4.6430. In the same way, the sum of case 3, 7, 8, 9, 10, 11 to other case similarity are: 4.5594, 4.6232, 4.8734, 5.0733, 4.3732, 3.6319. So, case 9 is the largest of the case similarity, and is chosen to be the representative case. The representative case results are shown in table 5.

Table 5.Representative Case

Case	Specific case	Representative case
1	{6}	{6}
2	{5,13}	{5}
3	{4,12}	{4}
4	{1,2,3,7,8,9,10,11}	{9}

5.2. Example of New Case Retrieval

As a new inspection fault phenomenon that cooling water temperature is too high, it retrievals the most matched case from the engine fault cases. The engine inspection failure case is shown in table 3.

First, according to the preliminary search strategy, users judge fault phenomenon in which part of the survey process, that is engine inspection fault. Through the preliminary search interface, users found the corresponding engine inspection fault cases in the tree control.

Second, according to the prompt of new case input dialog box, enter the new case.

C= [1.27, 0.053, 1.727, 2.315, 1411.497, 9.374]

Third, According to the rough sets based algorithm, determine the engine inspection attributes weights.

Weight= [0.1, 0, 0.07, 0.15, 0, 0.1, 0.3, 0.1, 0.2, 0.08, 0.23, 0]

Fourth, set similarity threshold of a representative case θ_1=0.2 , set similarity threshold of a specific case θ_2=0.8 , and calculate the similarity. Similarity calculation result is shown in table 6, 7 is the exactly matched case, inspection results are shown in table 7.

Table 6.Case Similarity

Representative case	Specific case base	Similarity
1	1	0.4082
1	3	0.8023
1	4	0.5043
1	6	0.6043
1	7	0.9235
1	8	0.5000
1	9	0.4323
1	10	0.3546
1	11	0.5634
1	12	0.7065

Table 7.Inspection Results

Case number	Engine 7
Inspection mode	Construction inspection
Inspection process	Engine inspection
Fault type	Cooling water temperature is too high
Reason and solutions	
Pipe blockage	Clean the pipes
Damage of the pump	Clean or replace the pump
Cylinder cushion is burned through	Repair or replace
Cylinder cracks	Replace the cylinder

The last, case study, in order to improve the quality of study, the new case is saved by the system.

6. Conclusion

An information support technology of case-based reasoning to support ship inspections has been discussed. The faults in the marine engine fuel system and cooling system were investigated as the case studies using the proposed information support technology. The inspection results show that: (1) To improve the quality of ship inspections, an advanced strategy of case-based reasoning was proposed; (2) Methods of expressing the inspection case and determining the characteristics weight vector were examined, and a “normative inspection case representation” was newly defined; (3) In order to improve the efficiency of inspection and support new inspectors, an indexed tertiary case library's or-ganization structure was proposed, in which the K-nearest neighbor method to calculate the similarity between cases was used. A distributed retrieval strategy of nearest neighbor method was adopted to improve the retrieval efficiency and shorten the retrieval time; (4) Methods of the case base organization and the new case retrieval were examined. Further, a ship inspection case management were introduced. Some examples were shown by calculating the data. As a result, this work has confirmed that the case-based reasoning can be managed and used in ship inspection. By using the results of this study, we would optimize the inspection of ships in future research.

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